MONOPOLISTIC COMPETITION IN INDONESIAN PETROLEUM INDUSTRY

Sujoso Sukarno

LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIF. 93940

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

MONOPOLISTIC COMPETITION
IN INDONESIAN
PETROLEUM INDUSTRY

by

Sujoso Sukarno

Thesis Advisor: Paul M. Carrick

Approved for public release; distribution unlimited.

T155707

MONOPOLISTIC COMPETITION IN INDONESIAN PETROLEUM INDUSTRY

by

Sujoso Sukarno
Major, Indonesian Navy
Drs., Bandung Institute of Technology, 1969

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1973

LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIF. 93940

ABSTRACT

Competition has been considered to be the prime force which leads to an optimal solution of the economic problem. But the underlying assumptions used in the current equilibrium theory are so empirical, such that in the practical world there just is no competition as proposed by the theory.

In fact, in real life economic competition does not exist in its pure form, but in a more realistic form instead: the monopolistic competition. A game theoretical approach is implemented to find answers to the issues of this particular phenomenon.

Petroleum environment in Indonesia provides the structures for the economic analyses.

TABLE OF CONTENTS

I. INTRODUCTION----------7

II. THE ECONOMICS OF A MARKET----------9

A. COMPETITIVE MARKET----------10

B. MONOPOLY----------14

C. DUOPOLY AND OLIGOPOLY----------16

III. CONCEPTS OF GAME THEORY----------21

A. THE NECESSARY BACKGROUND----------21

1. General Features----------21

2. Utilities----------22

3. Strategies----------23

B. THEORY OF THE CORE----------25

1. Characteristic Function----------25

2. Stable Set----------27

3. The Core of the Game----------28

4. Further Development of the Game----------29

C. AN ILLUSTRATION OF TRADING SITUATION----------32

IV. THE PETROLEUM INDUSTRY----------35

A. HISTORICAL CHRONOLOGY----------35

B. TYPES OF CONCESSION AND CONTRACT AGREEMENT----------36

1. Prior to 1960 Agreements----------37

2. Post 1960 Agreements----------39

3. Current Situation----------41

C. COST ANALYSIS IN OIL PRODUCTION----------43

D. SUMMARY OF DATA----------45
1. Total Oil Production----------45
2. National Companies' Production----------46
V. MONOPOLISTIC COMPETITION----------48
A. MONOPOLISTIC COMPETITION VS GAME----------48
B. CONCEPT OF A SOLUTION----------50
1. Balanced Set----------51
2. Assumptions of the Model----------53
C. NON-EMPTY CORE----------54
D. THE POWER OF THE MONOPOLIST----------56
1. Subset A vs Subset D----------58
2. Within the Subset A----------59
E. SOME NUMERICAL EXPOSITIONS----------62
VI. COLLUSION VS COMPETITION----------68
A. THE NATURE OF COLLUSION AND COMPETITION----------68
B. EFFICIENT INDUSTRY ORGANIZATION----------71
C. CONCLUDING REMARKS----------74
LIST OF REFERENCES----------75
INITIAL DISTRIBUTION LIST----------77
FORM DD 1473----------78

LIST OF FIGURES

Figure 1A----------11

Figure 1B----------12

Figure 2----------14

Figure 3----------17

LIST OF TABLES

Table 1----------45

Table 2----------46

Table 3----------46

Table 4----------46

Table 5----------46

I. INTRODUCTION

This paper explores the issues of the economic theory that free competition has become recognized as just a limiting case of an economic organization. One main reason for rejecting the study of more aspects of competition is that it fails to explain the phenomenon of bargaining which pervades all of economic life. Wherever bargaining occurs there is no pure competition.

Chapter Two reviews briefly the basic classical mechanism in securing the maximum efficiency under competition. Violations of the preconditioned assumptions for pure competition will result in forming other kinds of market structure: monopoly, duopoly and oligopoly are also considered.

Utility theory, principles of individual and group rationalities, dominance and stable sets leading to the theory of the core are stressed in the third chapter as an exposition of the game theory.

Chapter Four deals with the historical background of the petroleum industry in Indonesia and the existence of a monopolistic competition among state enterprises. A summary of data serves for an analytical model discussed in the following chapter is also presented.

Chapter Five derives the conditions of an equilibrium in a non-competitive form of a market; a process of showing the non-empty set of solutions, choosing a solution that has the biggest monopolist's power and ends up in a collusion.

The last chapter discusses how and when players in an economic game should collude or compete, and concludes the justification of the collusion in the petroleum industry.

II. THE ECONOMICS OF A MARKET

Any economy, whatever its cultural and political traditions may be, must solve the following so-called economic problems:

(a) What end products to produce, and how much of each to produce both in current and future time periods.

(b) How to produce each end product, and specifically how to allocate resources.

(c) How to divide up end products among the members of society.

One way to solve the problem is through the market system approach. Under this approach, a market is an economic environment that consists of two sets of participants: the firms that produce and the consumers. It involves two broad conceptions, one emphasizing the conducts of the sellers and buyers, the other the market structures. The sellers and buyers make their decisions in response to prices which are the results of the interaction of supply and demand forces on the market. Each participant seeks to make the best of the market conditions, by maximizing profit or subjective utility. This process is just like making a contract and remaking it until no participant can make himself better off. The process of contracting and recontracting is usually referred to as a tatonnement process. If initial

contracts do not lead to an equilibrium in the sense of clearing the market, i.e., equating supply and demand, pairings of buyers and sellers; they are called off and new contracts are made. This situation repeats itself until no excess supply or demand is supposed to exist. And during that process the aggregations of participants are accomplished through bargaining, forming coalitions which will result in several types of market structures. Major market structures are defined in terms of the number of sellers and buyers. Treating the number of sellers to be a variable and the buyers infinite, there exist two extreme cases of market structures: if there is only one seller then it denotes a monopoly, if there are many sellers it denotes a competitive market.

This paper is concerned only in the number of firms and the quantity they produce.

A. COMPETITIVE MARKET

Figure 1A and 1B review the conventional analysis of an equilibrium in a competitive market. At the beginning the market is observed to have a short run supply curve S_1, which constitutes the summation of all firms' marginal cost curves. The market price OX_1 is viewed by the firms as a given parameter. The firm maximizes its profit by producing

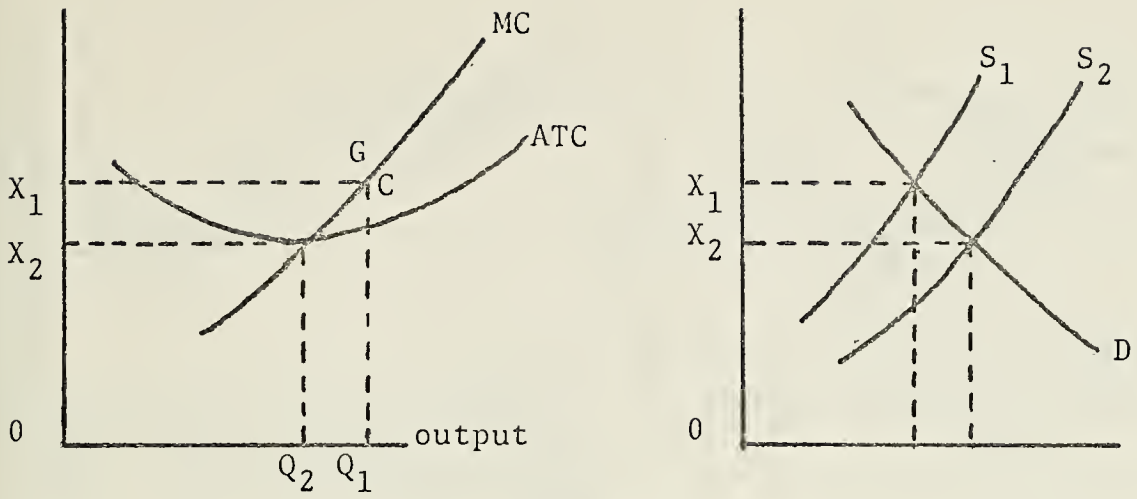
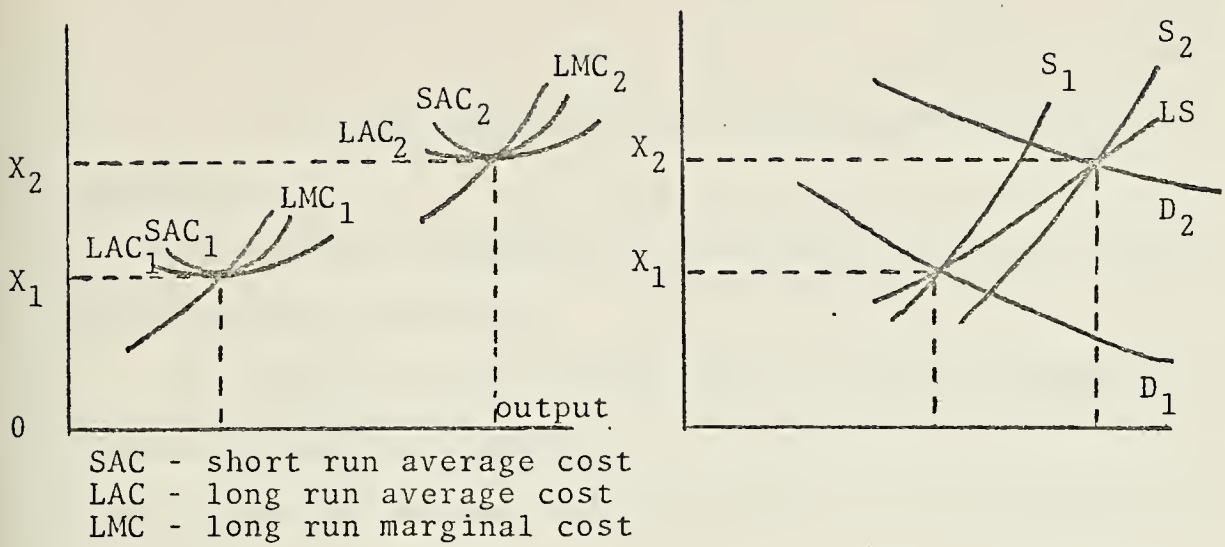


Figure 1A

OQ_1, i.e., operates at marginal cost MC equals the market price. It receives profit as large as per unit profit GC times the number of units produced OQ_1. In short run the market is said to be in equilibrium if the excess demand is zero. In long run, the market is in equilibrium if the excess demand is zero and each firm in the market earns zero profit. Because the profit in Fig. 1A is positive, then it can not be a long run equilibrium. New firms will be induced to enter the market, adding new marginal costs to the supply curve which results in shifting it to S_2. Entries will continue expanding firms' output, driving the price into equality to the average total cost ATC. The firm operates at MC equals the price OX_2 by producing OQ_2 at zero profit.

In the long run, if price changes the process of adjustment is usually believed to take two phases. In the first phase



SAC - short run average cost
LAC - long run average cost
LMC - long run marginal cost

Figure 1B

the firms move to a new short run equilibrium the intersection of S_1 and D_2. As investment leads to a new industry capacity, the capital expansion brings about a shift in second phase from S_1 to S_2. Price will once again reach a long run equilibrium position. If the long run supply curve (LS) is horizontal then it defines a constant-cost industry, i.e., the long run equilibrium price tends towards some constant level as the industry expands. There are also cases where LS increases or decreases depending upon the formation of the new S_2.

For a market to be competitive, the following conditions must hold:

(a) There must be many firms acting independently, and each firm is small enough relative to the size of the market.

(b) Entry into (and exit from) the market must be free.

(c) There is no collusion among the sellers or buyers.

(d) The goods produced are divisible and each unit is homogeneous.

(e) General knowledge of the market prices must exist among sellers and buyers.

(f) Market prices must be free to vary in response to changes in market forces.

(g) Market prices are independent from the actions of the sellers and buyers.

A competitive market, in the long run equilibrium state, has the following three general properties:

(a) The cost of producing the last unit of output is equal to the price paid by consumer for that unit.

(b) The price being equal to the average total cost avoids the supra-normal economic profits.

(c) Each firm produces output at the minimum point on its ATC curve. Thus resources are employed at maximum production efficiency.

It is the product of the current theory in saying that the market alone allocates resources optimally, presumably under free competition. If this is to be a description of reality, then it must also explain the consequences of the existence of monopoly, duopoly and oligopoly. Furthermore, the view also overlooks the phenomenon of prices being

formed by political processes, a surrogate market mechanism. The existence of governments, local or national are completely forgotten in the sense that their influences are being ignored.

B. MONOPOLY

Monopolists differ from the competitive firms in one essential respect: the firm is the supplier of the industry's output. Figure 2 shows the appropriate curves used in the discussion

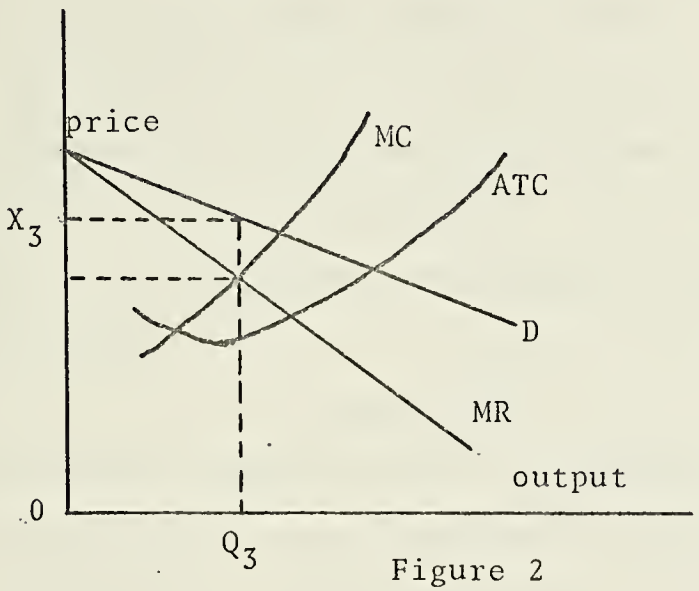


Figure 2

The monopolist maximizes its profit by setting X, the price per unit produced. So, if the firm's demand function is:

$$X = f(Q)$$

where Q - the quantity produced, then the profit function:

$$P = R - TC$$

where R - firm's revenue, TC - firm's total cost, functions of Q. The necessary condition for maximized profit is $\partial P/\partial Q = 0$.

Thus,

$$\partial R/\partial Q = \partial(TC)/\partial Q, \text{ or } MR = MC$$

that is: marginal revenue equals marginal cost.

Revenue is $R = XQ$, so that:

$$M = X + Q\ \partial X/\partial Q = X(1 + \frac{Q}{X}\frac{\partial X}{\partial Q}) = X(1 + 1/\varepsilon)$$

Thus, for a monopolist to define his new profit maximized output when the demand function shifts, he needs to know the price elasticity ε at various prices.

Suppose the firm does have a linear demand function:

$$X = a - bQ$$

where a and b are positive constants, X and Q are as defined. Its revenue:

$$R = aQ - bQ^2$$

Its marginal revenue: $MR = X + Q(dX/dQ) = a - 2bQ$. The firm with market power knows that to sell an additional unit of output, it must reduce its price to the customer for that unit. If it is unable to practice price discrimination, the firm must also reduce the price to all customers, who would have bought the product even without price reduction. Thus, the marginal revenue is equal to the price paid by

the marginal customer plus the change in price necessary to attract him multiplied by the number of units which would have been sold without the corresponding price reduction.

The profit maximizing firm will expand its output as long as the marginal revenue exceeds the addition to cost from producing that unit. The monopolist finally operates at MR = MC, which implies that $X_3 > MC$. He actively seeks for a maximum net return, having a choice of output and giving the least total cost for the total output. Therefore maximum net revenue (= profit) and maximum efficiency are consistent.

C. DUOPOLY AND OLIGOPOLY

Assuming that firms seek to maximize profits, when either competition or monopoly prevails there exist solutions to the firms' price and output decision problem. With rivalry among the few the case is different. Each firm recognizes that its best choice depends upon the choices its rivals make. The firms are interdependent, and their decisions depend on the assumptions they make about the rivals' decisions and reactions. The argument then involves a duopoly (when there are two firms) or an oligopoly (when there are more than two firms).

Figure 3 shows an example of a duopoly situation. Let each monopolist assume that he knows the market demand

curve and his competitior's output. Also each chooses his profit maximizing output on the assumption that his competitor's output will remain unchanged.

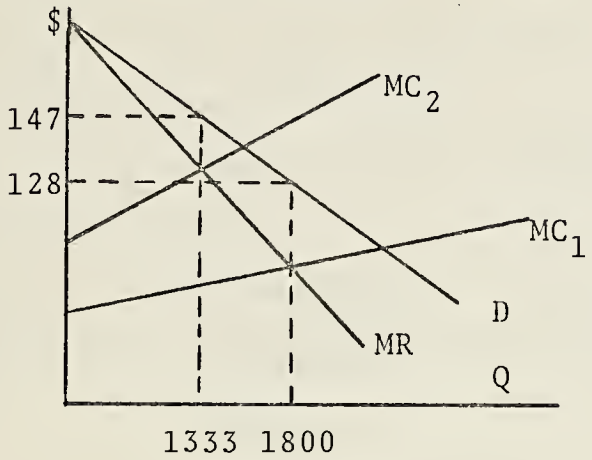


Figure 3

Suppose the firms' demand functions are:

Firm 1: $X = 200 - 0.04\ Q_1$

Firm 2: $X = 200 - 0.04\ Q_2$

Although the firms' demand functions are of the same form, as it will be shown that each firm will have less profit if it adopts its rival's price. The market's demand function: $X = 200 - 0.02(Q_1 + Q_2)$. Further, let:

$$TC_1 = 50{,}000 + 20\ Q_1 + 0.01\ Q_1^2$$

$$TC_2 = 20{,}000 + 40\ Q_2 + 0.02\ Q_2^2$$

such that:

$$MC_1 = 20 + 0.02\ Q_1$$

$$MC_2 = 40 + 0.04\ Q_2$$

As a monopolist, firm 1 operates at $MR_1 = 200 - 0.08\ Q_1 = MC_1$,

which resolves: X_1 = \$128,- and Q_1 = 1800 units. If firm 2, having the same demand function, were to behave as firm 1 does, then X_2 = \$128,- and Q_2 = 1800 units. But that is not the case. Firm 2 has its own cost function. In similar manner, firm 2 will have:

$$X_2' = \$147,\text{-} \text{ and } Q_2' = 1333 \text{ units}$$

The profits are shown:

Price/unit	Firm 1's profit	Firm 2's profit	Total profit
128	112,000	73,600	185,600
147	100,950	86,667	187,617

It is clear that each firm is worse off at its rival's price. Hence each would prefer to see its own favored price set on the market. This becomes a conflict situation. One way to solve it, is for the firms to get a compromise among their conflicting preferences through meetings, collusive agreements or bargaining. But this means a sacrifice in pricing independence. Another way is for the firm preferring the lowest price to impose its will on the other firm. This is plausible, since customers will surely come to a lower price seller, so that the firm with the lowest price preference has a distinct advantage over its rival. If the firm with the high price attempts to hold the price up despite its market share lossess, the low price firm is forced to get more customers and hence supply more than the quantity of output which maximizes its profit. Or if the high price firms is

disatisfiedwith its profit at the low price firm's favored price, it may threaten its rival to get into more appropriate cooperation.

The joint profit equation:

$(Q_1+Q_2)(200-0.02(Q_1+Q_2)) - (50000+20Q_1+0.01Q_1^2) - (20000+40Q_2+0.02Q_2^2)$

When this function is maximized with respect to their output, the optimal values are:

$$Q_1 = 2500 \text{ and } Q_2 = 750$$

The market price is found from the market demand function:

$$X = 200 - 0.02(2500+750) = \$135,-$$

The joint profit is \$215,000- which is distributed:

Firm 1's profit: \$175,000,-

Firm 2's profit: \$ 40,000,-

Firm 2 can surely do better at its own preferred price or even at its rival's, and it is not apt to cooperate in the joint effort. Thus, when marginal costs vary among firms, it is conceivable that no set of price-quantity choices consistent with independent actions taken by the firms will maximize collective profits.

Within oligopolistic market, where more than two firms get into the market, conflicts arise which unless resolved through collusive agreement, will interfere with the maximization of collective monopoly profits.

But most real economic situations are composite of both competition and monopoly. Markets that are neither purely

competitive nor pure monopolies belong in the broad category called monopolistic competition. The most typical features of monopolistic competition are:

(a) The interdependency among the firms in the market.

(b) The uncertainty about the actions of one's rivals.

It is the purpose of this paper to study monopolistic competition within a petroleum market using game theoretical language as a tool of analyses. For that reason, the exposition of game theory in the following chapter is in order.

III. CONCEPTS OF GAME THEORY

A. THE NECESSARY BACKGROUND

The word game is associated to rules, players, moves, strategies, pay-offs, some concepts of competition and cooperation, and the importance of information. So, a game contains the concept of a conflict situation in economic life.

1. General Features

Game theory is concerned with situations which have the following features :

a. There must be at least two players. The word player is used to denote a separate decision making unit in the context of the game. A player wishes to maximize some objectives and is in control of certain actions which influence the result of the game.

b. The game begins as one or more players make a choice among a number of specified alternatives. The methods and ways to conduct the game are described in the rules of the game, those are descriptions of what constitute a player's move, his state of information prior to his choice of move from a set of alternatives, and also his pay-off configuration

c. After the choice associated with the first move is made, a certain situation results. This situation determines

who is to make the next move and also what alternatives are available to him according to the rules given.

d. The choices made by the players may or may not become known. In an economic situation, a player may be able to guess with probabilistic certainty about other players' moves. Games in which all choices of all players are known to everyone as soon as they are made, are called games of perfect information. These games are distinguished from the opposite category of games: games of imperfect information.

e. The rules of the game include a termination rule which denotes that the game ends. And prescribed to that termination rule is a condition that determines a pay-off to each bonafide player, i.e., a player who makes choices and receives pay-offs. In an economic situation, these pay-offs may constitute profits in money value or in other measures of utility.

2. Utilities

In game theory it is assumed that the magnitude assigned to the pay-off denote the worth of that pay-off to the respective player. Since it bears a concept of magnitude then it requires a specification of the scale to be used. Utilities are pay-offs measured in an interval scale, which have the following properties:

a. A system U of some entities u, v, w,...etc.

In U a relation is given: $u \succ v$; and for any number δ, $0 < \delta < 1$, ther is an operation: $\delta u + (1-\delta)v = w$. Those entities satisfy the following axioms:

(1) Complete ordering:

(a) For any two entities one and only one of the follosing relations holds: $u = v$, or $u \prec v$, or $u \succ v$.

(b) $u \succ v$, $v \succ w$ implies that $u \succ w$.

(2) If $u \succ v \succ w$, then exists an δ such that $\delta u + (1-\delta)w \succ v$

b. Those axioms imply the existence of a correspondence between the entities and a real valued function V, such that:

(1) If $u \succ v$, then $V(u) > V(v)$

(2) $V(\delta u + (1-\delta)v) = \delta V(u) + (1-\delta)V(v)$

Or in words, a set of pay-offs that comprises a preference relation on U which is linear and transitive, is associated with a utility function V, which is invariant with respect to a linear transformation.

3. Strategies

The importance of the idea of strategy comes from the resulting conceptualization of a game. A plan of moves may contain rigid actions if it has a few contingent decisions. In game theory flexibility is irrelevant to the notion of a strategy. A strategy already contains in it

all contingencies which can possibly arise. Everything that can happen in the course of a game is known. What is not known, is the way the opposing player will actually choose each of his moves. A strategy is a plan that provides for every possible choice on the part of the other player, essentially it is a complete description of the course of action.

Suppose a set of players is specified by:

$$I = (1, 2, \ldots n)$$

To each i^{th} player a set of strategies is assigned:

$$S_i = (s_1^i, s_2^i, \ldots, s_m^i)$$

A utility function V is defined on a termination of the game:

$$V_i(\ldots, s_j^i, \ldots, s_1^k, \ldots) = u$$

where the i^{th} player is to receive u utiles when he uses his j^{th} strategy, while the other players pick their own strategies.

For simplicity, denote the rest of the strategies of the (I-i) players by s^k. The best response of the i^{th} player with respect to s^k, is s_*^i such that:

$$V_i(s_*^i, s^k) > V_i(s^i, s^k), \text{ for } \forall s^i \in S_i$$

Strategy s_o^i is dominant with respect to s^i, if:

$$V_i(s_o^i, s^k) > V_i(s^i, s^k), \text{ for } \forall s^k \in S_k$$

The players in choosing their strategies rely on their rational behaviors:

a. Individual rational behavior.

Each player will make his choice among strategies available to him that will give him the biggest pay-off.

b. Group rational behavior.

If by colluding the players will be better off than what they get alone, then they tend to make up for cooperation.

The process of cooperation may take several forms. The two extreme cases are: if the players in a game act and behave individually, i.e., there is no binding agreement, no negotiation or trust and no communication is possible among the players, the game is called non-cooperative; if all the players constitute one compact decision making unit, the game is called bargaining game. The physical realization of cooperation is called coalition. Thus the set of players I can be partitioned into coalitions in various coalition structures.

B. THEORY OF THE CORE

1. Characteristic function.

One level in the game theory where conflict situations are discussed in an abstract form is called the theory of games in characteristic function form. In this framework, the strategies available to the players are also abstracted. The only givens of the game are the pay-offs

which each of the several possible coalitions can assure for himself. The utiles of the pay-off are assumed to be in some conservative and transferable quantity, so that additivity property of pay-offs in a coalition is applicable.

The specification of minimum joint pay-offs which can accrue to each possible coalition constitutes the characteristic function of the game. This function acts as the utility function that transforms a set of players into real numbers, expressing a pay-off in terms of some utiles.

Let a game be played by n players:

$$I = (1, 2, \ldots, n)$$

The characteristic function is defined as:

$$W : I \dashrightarrow R^1 \qquad (1)$$

such that:

(a) $W(\emptyset) = 0$

(b) $W(I) = K$

(c) $W(S) + W(T) \leq W(S \cup T)$, when $S \cap T = \emptyset$

(super-additivity property)

where $S, T \subset I$ and if $W(S) + W(\bar{S}) = K$, $\bar{S}$- the complement of S with respect to I, the game that has this additional property is called constant sum game.

The principle of individual rationality implies that no player can be induced to accept any pay-off which is less then the value of the characteristic function on that

player -- the value of the game to him. But in some way, group rationality also drives the players to bargain in forming coalition which may give him a higher pay-off.

Let any disbursement of pay-off among the n players be denote by an n-tuple:

$$\vec{Z} = (z_1, z_2, \ldots, z_n) \tag{2}$$

where z_i - the pay-off to the i^{th} player.
Individual rationality is expressed as:

$$z_i \geq W(i), \; i = 1, 2, \ldots, n \tag{3}$$

Group rationality is expressed as:

$$\sum_{i \in S} z_i \geq W(S), \text{ for S a coalition.} \tag{4}$$

In particular, a bargaining may form in a grand coalition, then:

$$\sum_{i \in I} z_i = W(I) \tag{5}$$

2. Stable Set.

The set of disbursements that satisfies equations (3) and (5) is called the set of imputations. A pay-off vector $\vec{Z}$, in the form of equation (2), that belongs to this set is called an imputation.

The concept of dominace is extended to be applicable in the set of imputations.

Let the set of imputations be:

$$\mathcal{Z} = (\vec{Z} / \; z_i \geq W(i), \sum_{\forall i} z_i = W(I)) \tag{6}$$

Let S be a coalition, a subset of the set of all players I. If $\vec{Z}$, $\vec{Y} \subset \mathcal{Z}$, then $\vec{Z}$ is called to dominate $\vec{Y}$ via S:

$$\vec{Z} \ \text{dom}_S \ \vec{Y}$$

when the following holds:

$$z_i \geq y_i, \ \forall \ i \in S$$
$$Z(S) = \sum_{i \in S} z_i \geq W(S) \tag{7}$$

Define the dominion of Z via coalition S to be:

$$\text{Dom}_S \ Z = (\vec{Y} \in \mathcal{Z} / \vec{Z} \ \text{dom}_S \ \vec{Y}) \tag{8}$$

The dominion of R, for any $R \subset \mathcal{Z}$

$$\text{Dom}_S \ R = \bigcup_{Z \in R} \text{Dom}_S \ Z \tag{9}$$

$$\text{Dom} \ R = \bigcup_{S \in I} \text{Dom}_S \ R \tag{10}$$

R, a subset of the imputation set $\mathcal{Z}$, is stable if:

$$R \cap \text{Dom } R = \emptyset$$
$$R \cup \text{Dom } R = \mathcal{Z} \tag{11}$$

3. The Core of the Game.

The set of disbursements that satisfies equations (3), (4) and (5) is called the core of the game. Since it satisfies equation (6), then the core of the game is contained in the imputation set $\mathcal{Z}$.

Equation (4) implies that the corresponding imputation $\vec{Z}$ is the best imputation via coalition S. In other

words, no player can be better off, except by those imputations which are in the core. Accordingly the core C also satisfies equations in (11). Thus,

$$C \subset R$$
$$R \cap \text{Dom } C = \emptyset \tag{12}$$

In general, there is a number od redundant inequalitites described by the imputations in the core. A substantially smaller set of inequalities is sought, which can produce necessary and sufficient conditions for the existence of a non-empty core. The objective is then to find an imputation among imputations in the set of imputations, which will give insights of the situation of conflicting players. The core being a subset of any stable set (12) is only a solution concept. In the succeeding discussions the core will be associated with a balanced set by which the non-emptiness of the core can be shown.

4. Further Development of the Game.

Sometimes, in order to simplify the theory and to be able to compare different games conveniently, the value of the characteristic function is normalized in the following manner.

Define two constants:

$$\beta = 1/(W(I) - \sum_{i \in I} W(i))$$
$$\gamma_i = -\beta W(i) \tag{13}$$

Since the characteristic function acts as a utility function, then it is invariant with respect to a linear transformation. Hence:

$$W'(i) = \beta\, W(i) + \gamma_i = 0$$

$$W'(I) = \beta\, W(I) + \sum_{i \in I} \gamma_i = 1$$

A game is said to be normalized when:

$$W(i) = 0, \forall\ i \in I \text{ and } W(I) = 1 \qquad (14)$$

Thus any game can be transformed to its normalized form by using the constant defined in (13).

The inequality mentioned in (1c) has a weak meaning, in the sense that the equality part does not add any information. If two coalitions will receive just the same pay-offs when they collude, then they need not do that in the first place. It is more apropriate to express [12]:

$$W(S \cup T) > W(S) + W(T), \text{ when } S \cap T = \emptyset \qquad (15)$$

The game that has this property is called essential. If the equality applies the game is called inessential.

In general, inessential game will have the following equility:

$$W(S) = \sum_j W(S_j) \qquad (16)$$

where

$$S = \bigcup_j S_j,\ S_j \cap S_k = \emptyset,\ \text{for } j \neq k$$

So that, it never pays to join a coalition in an inessential game.

Then, the players in an essential game are motivated to form blocking coalition, a coalition whose inputations are in the core of the game.

Let a game G(I,W) be described by the set of players I and its characteristic function W. If the game is normalized then equations in (14) are applicable. Assume further that this game is essential, so that equation (15) applies:

$$W(S) + W(\bar{S}) < 1$$

where $\bar{S}$ - as defined in (1).

A theorem is proposed:

THEOREM 1: All constant sum, essential games have empty cores.

Proof:

Suppose that an imputation $\vec{Z}$ is in the core. Then the following will hold; using the notation in (7):

$$z_i \geq 0, \forall\ i$$
$$Z(S) \geq W(S)$$
$$Z(\bar{S}) \geq W(\bar{S})$$

The sum of the right hand side can never reach 1, which implies that: $Z(I) \geq W(I) \neq 1$. This contradicts the definition of the core. Since $\vec{Z}$ is arbitrary, then it is concluded that the core is empty. QED.

For this reason, then the game that will be dealt is non-constant sum and essential.

C. AN ILLUSTRATION OF TRADING SITUATION

The classical propostition of a competitive market is that there exists a common price in the market. And this is accomplished by assuming that the supply curve consists of the summation of many firms' marginal cost curves. When there are only a few firms, market price may depend on individual action. Core theory is advantageous since it applies to any number of firms.

The following example shows how core theory comes to a solution of a market game, where a unit good is being exchanged.

Suppose there are a seller A and two buyers B_1 and B_2. The values of the characteristic function on every possible coalition are:

$$W(A) = a$$

$$W(B_1) = W(B_2) = 0$$

$$W(A,B_1) = \max.\ (a,b_1)$$

$$W(A,B_2) = \max.\ (a,b_2)$$

$$W(B_1,B_2) = 0$$

$$W(A,B_1,B_2) = \max.\ (a,b_1,b_2)$$

where a is A's reservation price for the one unit to be traded, and b_1, b_2 are respectively reservation prices for B_1 and B_2 in buying the one unit from A.

Assume further that $a < b_1 < b_2$, and $\vec{Z} = (z,y_1,y_2)$ an imputation. For $\vec{Z}$ to be in the core, the following inequalities must hold:

$$z \geq a$$

$$y_1 \geq 0$$

$$y_2 \geq 0$$

$$z + y_1 \geq b_1$$

$$z + y_2 \geq b_2$$

$$y_1 + y_2 \geq 0$$

$$z + y_1 + y_2 = b_2$$

The last equality is due to the group rationality and b_2 being the highest price as assumed, which implies:

$$y_1 \leq 0$$

The core inequalities can be reduced to:

$$y_1 = 0$$

$$y_2 = b_2 - z$$

$$b_1 < z < b_2$$

This set of equations is the solution of the game: seller A successfully sold the good to B_2 obtaining the highest bid. B_1 although failed to get the good, his presence narrowed down the range of price.

It is instructive to consider collusion between B_1 and B_2. Let B_2 being the more eager buyer agree to retain his bidding so that B_1 can get the good at a lower price. B_1 pays A a price X_1, $a < X_1 < b_1$. B_2 pays B_1 a price X_2, $X_1 < X_2 < b_2$.

But this situation will never happen, since A and B_2 can be better off by trading at a price z, $b_1 < z < X_2$, which forces the solution back to the core.

The main direction in the application of n-person game theory has been towards social and behavioral sciences. Most of the known solution concepts have found applications to economics. The formulation of economic problems as games has clarified many points and frequently various game solutions have added new insights. Monopolistic competition is one of such problems.

IV. THE PETROLEUM INDUSTRY

Petroleum industry in Indonesia is not organized under purely competitive conditions. Although the government takes a particular interest in the firms to ensure their profit makings no natural monopoly has emerged. The structure of the petroleum market can best be categorized within monopolistic competition.

Before applying the game theoretical tools developed in the previous chapter on a realistic situation of petroleum environment, a relevant understanding of how the petroleum industry comes into being is desirable.

A. HISTORICAL CHRONOLOGY

Oil was discovered by Zylker, a Dutchman, in North Sumatra as early as the year 1883. Since then, international companies have entered to make profits, such as Royal Dutch Co. in 1890, Shell Transport & Trading Co. in 1907, B(ataffsche) P(etroleum) M(aatschappij) in 1911 and Standard Oil (STANVAC) in 1912.

In 1930 the Dutch government in Indonesia created N(ederlands) I(ndiesche) A(ardolie) M(aatschappij), a government type company that controlled the oil activities through its counterpart BPM, a private profit making company with

50-50 profit sharing. BPM on the other hand contracted N(ederlandsche) K(oloniale) P(etroleum) M(aatschappij), N(ederlandsche) P(acific) P(etroleum) M(aatschappij) which were subsidiaries of STANVAC and CALTEX respectively, with a 40-40-20 profit sharing for BPM, NKPM and NPPM.

In 1938, BPM being the sole contractor raised its shares by 72-28 in its favor.

Between the years 1942-1945, during the Japanese invasion crude oil production fell from 30 million barrels to 20 million barrels annually.

In 1945, Indonesia proclaimed her independence. The oil production was worst in the interval of 1945-1947, it produced only 7-8 million per year.

The existing companies operating in the country consisted of three national companies: PERTAMIN, PERMIGAN and PERMINA and their counterparts: STANVAC, SHELL and CALTAX. NIAM was transformed into PERMINDO a state enterprise which also acted as partner for all foreign companies.

From the year 1948, crude oil production took off from 31 million barrels to 394 million barrels in 1972.

B. TYPES OF CONCESSION AND CONTRACT AGREEMENT

Early concession agreements were in general relatively simple documents. They usually gave exclusive rights of exploration and development over large areas of the host country. The common form of obligation for the foreign

companies was to pay royalties on the oil produced, which might be combined with a bonus payment upon signing. The concession period varied between 40 years to 75 years.

The changing shares of crude oil production over the years can be seen from the following percentages:

Company	1925	1938	1957	1963
SHELL	95	72	23	26
NIAM			10	3
STANVAC	5	28	20	11
CALTEX			47	55
PERMINA				5

The relationship between the government and the foreign companies can be categorized into:

1. Prior to 1960 agreements.

After the war in 1945, when the Indonesian took government, it was realized that foreign companies suffered a severe loss in terms of damaged plants and oil fields. A rapid reconstruction of the industry had to be arranged immediately. The rehabilitation of war damaged installations were very expensive in terms of foreign exchange. Therefore, the "let alone" agreement was proposed: the companies were permitted to retain the foreign exchange they received from the oil sales abroad for an agreed number of years, on the condition that they rebuild the oil and refinery industry.

However, the "let alone" agreement eventually came to an end. Individual companies faced different situations:

a. STANVAC arrangements ran to an end in 1951. But the company obtained a general permit to spend foreign currency on imports of equipment and services necessary to maintain and develop petroleum operation, and was granted a ten-year exemption from import duties on its supplies of capital goods and materials. In return, the company agreed to undertake a three-year development program estimated to cost $80 million.

b. At the end of 1953, CALTEX let alone agreement expired. The company signed a five-year agreement for foreign exchange matters on the STANVAC model including freedom from import duties. CALTEX also agreed to turn over $60 million worth of acceptable foreign exchange in lieu of building a refinery.

c. SHELL had its let alone agreement expired at the end of 1955. No precise information exists concerning the nature of its agreements with the government. But presumably the arrangement adopted were the same as for the other two companies.

The new agreements were considered advantageous with respect to import duties, expenditures on new equipments, exploration services and remittances of dividends to the parent companies overseas. So long as the rehabilitation

of the industry continued and crude oil exports could continue to earn substantial foreign exchange, the large petroleum companies retained a strong position face to face the government. However, the government negotiated a new profit division which amounted to something around 50-50 division of net revenue with the companies.

2. Post 1960 Agreements

Starting in 1959, the government undertook a number of contracts and long term agreements with foreign oil companies other than SHELL, STANVAC and CALTEX. They included a technical and financial assistance contract in 1960 between PERMINA and a Japanese group to rehabilitate the former SHELL fields in North Sumatra, in return for deliveries of crudes. This was one of the first production sharing between the host government and foreign enterprise.

The legislation of Law no.44 of 1960, concerning petroleum and gas mining, changed the legal status of foreign companies by stipulating that for the future all foreign companies could only act as contractors and could no longer have concession rights. The new law was exercised on the arrangements conducted between PERTAMIN and Pan American International, a subsidiary of Standard Oil of Indiana. Pan American did not get the concession rights, it could only make a contract to work for and supply PERTAMIN. This contract is of special interest, because it created the prototype of the agreements negotiated in 1963 with the three major oil companies.

The agreement gave Pan American a thirty-year exploration and development contract in a prospecting area of Sumatra. The area convered a total of 816 million acres, including a small off-shore sector of 8,436 acres adjacent to and partly surrounding CALTEX fields. Pan American contracted to pay $10 million bonus for its rights to explore and develop: $5 million at the time of ratification of the contract and another $5 million to be paid at the end of the first year in which oil exports averaged 15,000 barrels per day. The exploration period was arranged for six years with provision for two year extension and carried an investment for exploration of $28.5 million at the minimum. The contract was based on 60-40 profit division in favor of PERTAMIN.

Against this background of production sharing agreement the three major oil companies negotiated with the government to produce the following documents:

a. Each of the three companies gave up its concession rights granted under the old agreement, and agreed instead to acts as contractor for:

(1) CALTEX - PERMINA

(2) STANVAC - PERTAMIN

(3) SHELL - PERMIGAN

b. In exchange, they were awarded twenty year contracts to continue the exploitation of the old concession

areas. They were permitted to apply for thirty year contracts to explore and develop new areas adjacent to existing old concession areas. The new area contracts required immediate payment of cash bonuses of $5 million, and another $5 million when commerical production was established.

c. Marketing and distribution facilities were to be handed over to the national companies within five years at agreed prices.

d. Refinery assets would be transferred within ten to fifteen years according to agreed terms.

e. The operating profits of the international companies would be divided, as from June 1963, in the ratio 60:40 for the government and the company. But in any event the government receives a minimum payment of 20% of the gross value of the crude oil produced in any one year by a foreign company.

3. Current Situation.

In 1966, a new outlook on foreign participation in the oil industry appeared. The government realized how the oil industry had become an important contribution to the nation's economy. (In the last decade oil export averaged 58.5% dollar value of the total.) Since most of the exploration and extraction of oil take place in remote areas and desolate coastlines, foreign investment in petroleum provides a social capital in the form of roads, airfields, river channels and harbors.

In August 1968, the three national companies were merged under the name of PERTAMINA that acted as the sole national company, exercising two new policies: first, the exploration developments are intensified mainly on off-shore areas, second, any foreign company may become contractor and explorer as long as it operates on agreed terms. Among the new foreign companies are: Mobil Oil Corporation, Companie Francaise des Petroles, Union Oil, Continental Oil, Sinclaire-Phillips, Japex, Kyushu.

The new terms of agreements in some degree are production sharing agreements, although export sales would probably take place through the foreign company. To cover exploration and production costs, 40% of the crude sales from a given contractual area is taken by the contractor. Of the remaining 60%, the contractor retains 35% and the 65% goes to PERTAMINA. If production rises above 75,000 barrels per day the latter shares become 32.5-67.5. Production bonuses of $1.2 and $2.75 million are due when production reaches 30,000 and 60,000 barrels per day respectively. The periods of exploration and exploitation are generally ten and twenty years.

Several distinct features of the Indonesian oil and oil producing environments can be stated as:

(a) Most production comes from relatively shallow depth, less than 3,000 feet.

(b) The oil structures are typically small and scattered.

(c) The quality of the crude: Average degrees of API = 33.4, Sulpher contents = 0.001, Pour point = 95-105^{o}F, Gasoline yeilds = 65%.

(d) Transportation and distribution costs are relatively expensive.

C. COST ANALYSIS IN OIL PRODUCTION

The oil production process is conventionally divided into three stages: exploration, development and extraction. Exploration involves finding crude reserves by geological and geophysical prospecting methods and ultimately by drilling. Once reserves are found, producing capacity must be extablished, a field is developed by drilling additional wells on some specified pattern and providing equipment to gather, process and transport the crude. These first two stages overlap. Extraction, the final stage in the process, involves services that must be performed concurrently with the taking of the crude. These include pumping costs, maintenance, area supervision and where necessary, treatment of wells to improve productivity.

The cost of crude oil is measured by the replacement cost [2]: current exploration costs/barrels added to proved reserves through discoveries, plus current development costs/barrels added to proved reserves through extension and revision, plus current production costs/barrels produced.

Exploration costs are not directly assignable to crude production, although the expenses incurred affect the level of the other cost component. The main product of exploration effort is knowledge of a certain structure whether it is productive or not. The emphasis is placed on the development costs relative to the extraction costs, since the latter are barely significant if compared to the former.

Development outlays, as a type of capital formation, generate future production, so that the cost must be imputed to each barrel of crude produced.

A formal statement of a measure of development costs is as follows:

Let J - development investment

$q(t)$ - output of crude at time t attributable to J

e^{-rt} - discount factor applied to returns at time t with discount rate r

c - development costs per barrel of crude

τ - duration of production period

thus,

$$c = J \Big/ \int_0^{\tau} q(t)e^{-rt}\,dt \qquad (17)$$

In essence, the development cost which represents the production cost per unit of crude oil is inversely proportional to the output of crude.

D. SUMMARY OF DATA

1. Total Crude Oil Production.

The data presented are taken from volumes of "World Oil" of 1955 through 1969 and "PERTAMINA Oil Statistics", Statistics Division & Information Center, Jakarta, 1972.

YEAR	TOTAL BARRELS	BARRELS PER DAY
1955	85,921,000	235,398
1956	93,820,000	236,339
1957	114,283,221	313,105
1958	118,986,335	325,990
1959	137,253,191	376,036
1960	150,510,300	411,288
1961	155,182,271	425,157
1962	166,926,719	457,333
1963	165,068,022	452,241
1964	169,831,124	464,019
1965	177,043,060	485,049
1966	166,035,740	454,892
1967	178,859,521	490,026
1968	205,414,000	561,240
1969	269,000,000	736,986
1970	311,549,000	839,800
1971	325,614,000	892,500
1972	394,806,000	1,027,000

Table 1

2. National Companies' Production.

a. PERMINA:

YEAR	TOTAL BARRELS	BARRELS PER DAY
1962	9,226,552	25,278
1963	9,543,793	26.148
1964	8,813,166	24,080
1965	8,487,902	23,253

Table 2

b. PERTAMIN:

YEAR	TOTAL BARRELS	BARRELS PER DAY
1962	7,469,859	20,465
1963	5,777,453	18,825
1964	4,876,343	13,324
1965	4,253,203	11,653

Table 3

c. PERMIGAN:

YEAR	TOTAL BARRELS	BARRELS PER DAY
1962	964,348	2,642
1963	953,615	2,613
1964	865,680	2,365
1965	711,045	1,948

Table 4

d. The percentage of average production from the total in 1962-1965:

PERMINA	5.3%
PERTAMIN	3.3%
PERMIGAN	0.5%

V. MONOPOLISTIC COMPETITION

Monopoly and pure competition are discussed in Chapter II. Monopolistic competition is to be associated with a game as exposed in Chapter III. Since the conditions of monopolistic competition are distinctly different from those of pure competition or monopoly, it is necessary to make different assumptions concerning the model. As the range between the two opposite market structures encompass an extremely large variety of possible market conditions, there also exists a large number of environmental and behavioral specifications that may be used in setting up suitable theoretical constructs for analyzing various aspects of monopolistic competition. It is this diversity of situations that causes the absence of a general theory of monopolistic competition. Instead, there are different models and theories each designed to deal with a particular type of monopolistically competitive market.

A. MONOPOLISTIC COMPETITION VS GAME

Let a group of firms own some goods that they may exchange among themselves in any mutually agreeable way. Every firm seeks for a maximum gain by exchanging. The

result is a redistribution of goods among the firms that agree on the terms of the exchange. The process describes the firms forming a coalition that allocates or imputes the goods to its members. The goods may comprise physical goods or any other form of utility.

The freedom to exchange with any firm is the same as the freedon to join any coalition. Therefore, a firm will join that coalition offering it the best terms. The forming and dissolving of coalitions is equivalent to contracting and recontracting. The process continues until no firm can be better off by exchanging. The resulting set of coalitions and the allocations prescribed by the imputations constitute the core of the market. The set of all possible contracts resulting from the firms' pursuit of their interests is fundamental to a competitive market. The collision of self-interests force the imputations into the core. Thus, the core of the market contains all possible competitive equilibria.

Among those coalitions, whose imputations lie in the core, there may exist one particular firm that has the biggest power to prevent other coalitions, in which it is a member, from getting their guaranteed gains by the core. This particular firm is the monopolist, whose strength lies in his bargaining power created by the harm he can cause by refusing to exchange. Hence, the monopolist's power is measured by the difference between what others can get with him and what they can get without him. These combined behavioral phenomena

i.e., producing a monopolist within the context of competitive equilibria, comprise the monopolistic competition in economic sense.

There are three main mathematical problems which are encountered in studying games:

(a) The question of a general existence theorem, that is one would like to prove that any particular game in a certain model has at least one non-empty subset of imputation which is the solution of the game.

(b) One is interested in the mathematical nature of the various sets that form the solution of the game; i.e., is the set feasible or do the values converge.

(c) One would like to be able to determine explicitly the solution set(s) for the game.

B. CONCEPT OF A SOLUTION

In deriving the explanation of the presence of monopolistic competition, the following train of arguments is used:

(a) Showing the existence of the non-empty core of the game.

(b) Constructing a mechanism to get the players to compare their bargaining powers in forming coalitions which will then result in a single dominating monopolistic competition.

(c) Showing the condition of the imputation via that particular coalition, such that it is still an element of the core.

Before proceeding, some additional concepts of what are called solutions are appropriate.

1. Balanced Set.

In the attempt to find a solution of a game, one searches among the sets of imputations to get into the core. Unfortunately, many games have empty cores, so that this abstract concept of finding a solution is in vain. Ways are sought to get a measure to check the non-emptiness of the core. One of those ways is the application of linear programming method to the theory of the core.

Suppose in a general n-person game, $\vec{Z}$ denotes an imputation and W(S) denotes the characteristic function of the coalition S. For that imputation to be in the core, equation (4) must hold. And in addition the grand coalition condition (5) must also be satisfied.

Consider a primal linear programming problem of the following form:

$$\begin{aligned} &\text{min.} \sum z_i \\ &\text{s.t.} \sum_{i \in S_j} z_i \geq W(S_j) \\ &\qquad z_i, \text{ unrestricted} \\ &\qquad S_j, \text{ the } j^{th} \text{ coalition} \end{aligned} \tag{18}$$

The number of constraints in (18) is as many as the number of possible coalitions.

The dual problem is:

$$\max. \sum_{j/i\varepsilon S_j} d_j \; W(S_j) \tag{19}$$

$$\text{s.t.} \sum_{j/i\varepsilon S_j} d_j = 1$$

$$d_j \geq 0$$

Linear programming requires that the primal objective function equals to the dual objective function. Thus,

$$\min. \sum z_i = \max. \sum_{j/i\varepsilon S_j} d_j \; W(S_j) \tag{20}$$

Now, since equation (5) is satisfied, then (20) is less than or equal to W(I).

Hence, having (4), (5), (18) through (20), it is concluded that the core is not empty if and only if:

$$\sum_{j/i\varepsilon S_j} d_j \; W(S_j) \leq W(I) \tag{21}$$

which will be proved formally in the succeeding discussion In the mean time names can be given to the following statements. The set of coalitions (S_j) is a balanced set if it satisfies the constraints in the dual problem (19). A game is called a balanced game if for every balanced set equation (21) applies.

2. Assumptions of the Model

In order to be able to solve a game, some assumptions are needed concerning the nature of the players and the characteristic function.

a. The Nature of the Players.

The overall game involved is:

$$G'(I'W') \tag{22}$$

where $I' = (A, B, D)$

$A = (A_1, A_2, \ldots, A_K)$

$B = (B_1, B_2, \ldots, B_L)$

$D = (D_1, D_2, \ldots, D_M)$

A_k - k^{th} national oil company

B_1 - 1^{th} country that buys oil

D_m - m^{th} international company

W' - the characteristic function applicable in G'

G' represents the whole situation of the world oil economy. But this paper concerns only a subset of G':

$$G(I,W) \tag{23}$$

where $I = (A,D)$, A and D are as defined in (22)

W - the characteristic function applicable in G.

G represents the conflict situation within the Indonesian petroleum industry.

b. The Nature of the Characteristic Function.

(1) Within the context of discussion, it is assumed that the product under consideration is sufficiently homogeneous (crude oil) such that the total market demand can be represented by a single function.

(2) The price per unit of the good sold was earlier derived in G'(I',W') as a non-discriminated price. Within G(I,W) the price involved is considered to be given.

(3) Within the normalized G(I,W) the characteristic function is defined to be the percentage function of the averaged annual crude production. The domain of the function is the set of players of the corresponding coalition.

C. NON-EMPTY CORE

The existence of a non-empty core is associated with the concept of balanced set. The (essential) game G(I,W) satisfies the following equations:

$$\vec{Z} \in C, \text{ C, the core} \tag{24}$$

$$Z(S) \geq W(S), \text{ S a coalition}$$

$$Z(I) = W(I)$$

$$W(S) + W(T) < W(S \cup T), \text{ for } S, T \subset I, S \cap T \neq 0$$

Another theorem is proposed:

THEOREM 2: The game G(I,W) has non-empty core, if and only if it satisfies all balanced inequalities of (21).

Proof:

The proof consists of a sufficiency part and a necessity part.

The sufficiency part:

From (24),

$$Z(S_j) \geq W(S_j)$$

which by using the fact that d_j's are non-negative coefficients implies:

$$\sum_{j/i\varepsilon S_j} d_j \; Z(S_j) \geq \sum_{j/i\varepsilon S_j} d_j \; W(S_j) \qquad (25)$$

The notation in (7):

$$Z(S_j) = \sum_{i\varepsilon S_j} z_i$$

suggests that Z is an additive function. The constraints in (19) implies that:

$$0 \leq d_j \leq 1, \text{ for all } j$$

and

$$\sum_{j/i\varepsilon S_j} d_j \; Z(S_j) \leq Z(I) = W(I) \qquad (26)$$

Thus, combining (25) and (26) will give (21).

The necessity part:

From (21), the implication to (25) is immediate such that the group rationality condition is also satisfied. The definition of the characteristic function shows that:

$$W(S_j) \geq W(i) + W(S_j - i) \qquad (27)$$

The coalition is group rational, then:

$$Z(S_j) \geq W(i) + W(S_j - i) \tag{28}$$

If S_j is substituted by i and use $W(\emptyset) = 0$, (28) becomes:

$$Z(i) = z_i \geq W(i)$$

This is just the individual rationality.

The application of the group rationality on the whole set of players will give:

$$Z(I) \geq W(I) \tag{29}$$

But in a normalized game $W(I) = 1$ is the highest value of the game. Thus

$$Z(I) \leq W(I) \tag{30}$$

Equations (29) and (30) constitute the grand coalition condition $Z(I) = W(I)$. Now, since $\vec{Z}$ satisfies the three properties mentioned in (3), (4) and (5), $\vec{Z}$ is in the core. Hence the core is not empty. QED.

If a game can be shown to be balanced, then it is guaranteed that its core is not empty.

D. THE POWER OF THE MONOPOLIST

The game is given as usual by its characteristic function W(S), S a coalition. Every player has a certain contribution to the value of the characteristic function of any forming coalition, in which he is a member. This contribution of the i^{th} player to coalition S is expressed as:

$$W(S) - W(S-i) \qquad (31)$$

There are many ways for the i^{th} player to be included in any coalition S which ranges over all subsets of I.

Let the set of players be partitioned:

$$(i, S-i, I-S)$$

The corresponding numbers of players within each subset are respectively:

$$(1, n'-1, n-n')$$

Hence, the number of ways for the i^{th} player to form a coalition:

$$(1)!(n'-1)!(n-n')!$$

The number of ways to form a grand coalition is: n!
So that the probability of the i^{th} player joining coalition S:

$$(n'-1)!(n-n')!/n! \qquad (32)$$

The power to bargain constitutes the expected contribution of the i^{th} player, i.e., the expression in (31) weighted by (32) over all possible coalition; where $i \varepsilon S$:

$$\varphi_i = \sum_{S \subset I} (n'-1)!(n-n')!(W(S)-W(S-i))/n! \qquad (33)$$

where φ_i - the bargaining power.

The power of the monopolist appears as a result of a two step process. The first step: Members of coalitions whose

imputations lie in the core compare their bargaining power among themselves. The result of the first step process is a unique coalition whose members have the biggest bargaining power. The second step: Within this particular coalition, the members fall into a conflict situation in deciding which one of them becomes the leader of the coalition. This last step process is accomplished by the usual maximization of their profits.

1. Subset A vs Subset D.

Recall that subset A consists of the national oil companies: (A_1, A_2, A_3), and $D = (D_1, D_2, \ldots, D_M)$ are the international oil companies.

Consider the subset A, i = 1, 2, 3:

$$W(S-i) = 0, \text{ S any coalition such that } (S-i) \subseteq D \tag{34}$$

The reason for that is simply that any coalition, without the involvement of any one of the national companies, can not gain anything.

Then, equation (33) becomes:

$$\varphi_i = \sum_{S \subset I} (n'-1)!(n-n')!W(S)/n!; \text{ for } i = 1,2,3$$
$$= 0, \text{ for } i = 4, 5, \ldots \text{elements of D} \tag{35}$$

It has become obvious that only A_1, A_2 and A_3 have the (biggest) bargaining power, such that they consitute the unique coalition.

It is worthwhile to notice the property of φ_i as a function of n'. The summation itself is an increasing function. To show that φ_i increases whenever n' does, it is sufficient just to observe the weight of W(S), because the latter being the percentage function is an increasing function of n'. Use the Sterling formula: $k! = e^{-k}k^k(2\pi k)^{\frac{1}{2}}$ for the weight of W(S):

$$f(n') = (n'-1)!(n-n')!/n!$$

$$= (e(2\pi)^{\frac{1}{2}}/n^{n+\frac{1}{2}})(n'-1)^{n'-\frac{1}{2}}(n-n')^{n-n'+\frac{1}{2}}$$

For $1 \leq n' \leq n$, it is clear that f(n') is an increasing function. This means the more foreign companies that enter the market, the bigger is the bargaining power for (A).

2. Within the Subset A.

Consider the coalition (A). Its members are assumed to be group and also individually rational as previously defined in III..A. 3. a and b, thus they are profit maximizing companies.

Assume that: q_k - the number of units of good produced by the k^{th} company

$C(q_k) = c_k q_k$, the cost of producing q_k, a linear function of q_k.

c_k - the cost per unit

$Q = \sum_k q_k$, total units produced

and:

$X = 1 - bQ$, the scaled market price per unit.

The profit function of the k^{th} company is then:

$$P_k(q_k) = q_k X - C(q_k) \tag{37}$$

$$= q_k(1-bQ) - c_k q_k$$

$$= q_k(1-c_k-bQ)$$

The k^{th} company is called active if $q_k > 0$, i.e., $P_k(q_k) > 0$, or:

$$(1-c_k-bQ) > 0$$

$$Q < (1-c_k)/b \tag{38}$$

Equation (37) can also be written as:

$$P_k(q_k) = q_k(1-c_k) - bq_k(\sum_k q_k) \tag{39}$$

$$= (1-c_k)q_k - bq_k(q_k + \sum_{j\neq k} q_j)$$

$$= (1-c_k)q_k - bq_k^2 - b(\sum_{j\neq k} q_j)\, q_k$$

The necessary condition for a maximum of profit $dP_k/dq_k = 0$. Hence:

$$1 - c_k - 2bq_k - b\sum_{j\neq k} q_j = 0$$

or $$1 - c_k - 2bq_k - b(Q-q_k) = 1 - c_k - b(Q+q_k) = 0$$

$$Q + q_k = (1-c_k)/b \tag{40}$$

From (40) one deduces that $c_k < 1$, otherwise Q has no meaning. The subscript k is arbitrary so that (40) is applicable for all companies in (A).

Thus:

$$\sum_k (Q+q_k) = (1/b) \sum_k (1-c_k)$$

$$KQ + Q = (1/b) \sum_{k=1}^{K} (1-c_k)$$

$$Q = (1/b(K+1)) \sum_{k=1}^{K} (1-c_k) \qquad (41)$$

where K determines the number of companies that may be active within (A).

In order that equations (38) and (41) be satisfied, then K is the smallest integer such that:

$$(1/b(K+1)) \sum_{k=1}^{K} (1-c_k) \geq (1-c_{K+1})/b$$

or

$$\sum_{k=1}^{K} (1-c_k) \geq (K+1)(1-c_{K+1}) \qquad (42)$$

Equation (42) is very important in deciding how many companies may exist and be active, and eventually which one of them will hold the market leadership. The implication of (42) also requires a certain condition on the c_k's.

Using the fact that $0 \leq c_k < 1$ on equation (38) implies the following statement: If $c_j < 1$ and the j^{th}

company is active, then (38) applies. Also if (38) is true, then the j^{th} company is active. Consequently, this tautology implies that if the j^{th} company is active and $c_j > c_{j-1}$ then the $(j-1)^{th}$ company is also active. So, before using equation (42) in determining the number of active companies, the cost per unit of the corresponding companies must be ordered:

$$0 \leq c_1 < c_2 < \ldots < c_k < \ldots < c_K < 1 \qquad (43)$$

E. SOME NUMERICAL EXPOSITIONS

So far, the theoretical discussions which are confined within an abstract context have explained the following results:

(a) The core of a game contains imputations that are dominant than any other imputation in the imputation set. These imputations in the core are associated with the classical competitive equilibria. A way to show that the core is not empty is by investigating whether the game is a balanced game; i.e., a game that satisfies the balanced inequalities (21).

(b) Among the core imputations there may exist one particular imputation that corresponds to a unique coalition. The members of that coalition have the biggest bargaining power.

(c) Those members of the particular coalition fall into a conflict situation, where one of them may become the leader of the coalition and dissolve the other two. The company which has a lower production cost per unit produced, has a bigger chance to hold the market leadership.

The above results will be applied on a realistic situation of the petroleum industry:

Let the game be defined as in (23):

$$G(I,W)$$

$$I = (A_1, A_2, A_3, D_1, D_2, D_3)$$

W - the percentage of the averaged annual crude oil production.

Since W is a percentage function, then its highest value is 1, which coincides with the value of a normalized game. W seems to characterize a constant sum game, although it is not really the case as will be made clear in the following manner. If the game were constant sum, then:

$$W(S) + W(\bar{S}) = W(I) = 1$$

for all possible coalition S

where $S \cup \bar{S} = I$. This will mean that one coalition gains at the expense of the other. But it is just not true, because the partition (A,D) is not proper. When W(D) = 0, the total crude production of A will noticably diminish such that the calculation of percentage can not be compared with

those of other partitions. Thus, $W(A) \neq 1$, and partition (A,D) violates the requirement for the game to be constant sum. Hence, the game is non-constant sum.

a. For i = 1, 2, 3; i.e., A_1, A_2 and A_3:

$$W(S_j) \leq W(I) = 1$$

where S_j is the j^{th} coalition in which $i \in S_j$.
If there exists a number of positive coefficients d_j such that

$$\sum_j d_j = 1$$

then the following is obviously true:

$$\sum_{j/i\in S_j} d_j \, W(S_j) \leq W(I)$$

In other words, according to THEOREM 1 and THEOREM 2 the core of this game is not empty, and hence competitive equilibrium does exist.

b. During the years 1962-1965 Table 5 shows:

$$W(A_1) = 0.053$$

$$W(A_2) = 0.033 \qquad (44)$$

$$W(A_3) = 0.005$$

These percentages also show the proportion of production capabilities among (A). The portion produced by (D) is 1 - (0.053+0.033+0.005) = 0.909, the 0.091 is by (A).

According to the rules of agreement 65% of the 60% of crudes produced by (D) goes to the corresponding member of (A); this is: 65% x 60% x (0.909) = 0.3545.

Hence,

$$W(A_1,D_1) = (53/91)(0.3545) = 0.2065 \qquad (45)$$

$$W(A_2,D_2) = (33/91)(0.3545) = 0.1286$$

$$W(A_3,D_3) = (5/91)(0.3545) = 0.0195$$

It is clear that other coalition T results in W(T) = 0.

Applying equation (35):

$$\varphi_1 = 5!0!(0.053)/6! + 4!1!(0.2065)/6! = 0.0157$$

$$\varphi_2 = 5!0!(0.033)/6! + 4!1!(0.1286)/6! = 0.0098$$

$$\varphi_3 = 5!0!(0.005)/6! + 4!1!(0.0195)/6! = 0.0007$$

$$\varphi_i = 0, \text{ for } i = 4, 5, 6 \qquad (46)$$

It concludes that the first three players have the bigger bargaining powers. And among those players, A_1 has a chance to lead the market.

c. Using the values given in Table 5, equation (17) and (43), then the cost per unit of crude for the corresponding company in (A) can be ordered:

$$0 \leq c_1 < c_2 < c_3 < 1 \qquad (47)$$

Equation (42) becomes the set of inequalities

$$(1-c_1) \geq 2(1-c_2) \qquad (48)$$

$$(1-c_1) + (1-c_2) \geq 3(1-c_3)$$

It would have been proper if the values of c's were known, so that the determination of which company will lead the market can be ascertained. But, in any case the game theory argues that at most there are only two companies with the lowest cost per unit may become active.

d. Now that theoretical argumentation forces the companies in (A) to collude in facing those companies in (D), it will finally be shown that the imputation they get after collusion is bigger than before. Since the comparison that will be conducted concerns different period of time, one tends to suspect that there may be other factors involved: better management, improved technology etc. But the facts remain that practically none of those factors do happen. The companies just merge under one name and continue to operate with their same former facilities but different unified policy. Moreover, should there be any improved factors, their effects with respect to the discussion, are eliminated by the characteristics of the characteristic function.

Summing (44) and (45) to get the total gains:

$$W(I) = 0.2595$$
$$W(2) = 0.1616 \qquad (49)$$
$$W(3) = 0.0245$$

During the years after the sole merger appears, the averaged crude production data are as the following:

Total: 325,242,250 barrels/year (50)

PERTAMINA: 63,434,000 barrels/year

For proper comparison between situations before and after merging, the composition of companies is assumed to be the same for the latter case. The portion produced by (A), from (50): 0.195, by (D): (1-0.195) = 0.805. Using the same production sharing rule: 65-35 of the 60% crudes, then the total gains to (A) are: 0.195 + (65%)(60%)(0.805) = 0.50895. The imputation for the members of (A) is found by implementing the proportion of production capabilities (44):

$$z_1 = (53/91)(0.50895) = 0.29642 \qquad (51)$$

$$z_2 = (33/91)(0.50895) = 0.18456$$

$$z_3 = (\ 5/91)(0.50895) = 0.02797$$

It is quite obvious, by comparing (51) to (49), the reason why the national oil companies prefer to collude rather than individually face foreign contractors is that $z_i > W(i)$, for i = 1, 2, 3. That is so since other coalitions do not exist except those mentioned in (45).

VI. COLLUSION VS COMPETITION

Preceding chapters discuss the explanations of a particular model of monopolistic competition withing a petroleum industry, where three oil companies collude and operate as a single company.

But, in general, why is there not a monopoly in every industry? In order to be able to answer the question, one is urged to seek greater clarification of the two concepts, collusion and competition. This, in turn encounters the question of what determines the number of firms in an industry.

A. THE NATURE OF COLLUSION AND COMPETITION [20]

Consider an industry in which there are n firms that produce the same goods at constant and common price per unit:

$$X = F(Q) \tag{52}$$

where $Q = \sum_{i=1}^{n} q_i$, and q_i - the quantity produced by the i^{th} firm.

Assume that the i^{th} firm has the total cost of the form:

$$C_i = G_i(q_i) \tag{53}$$

The net revenue for the i^{th} firm:

$$R_i = Xq_i - C_i \tag{54}$$

The necessary condition for a maximum is of course $dR_i/dq_i = 0$. Thus,

$$\frac{dR_i}{dq_i} = \frac{d}{dq_i}(Xq_i - C_i) = \frac{d}{dq_i}(F(Q)\ q_i) - \frac{d}{dq_i} G_i(q_i) = 0$$

and hence:

$$X + q_i(dF/dQ)d(\sum_j q_j)/dq_i - dG_i/dq_i = 0 \qquad (55)$$

Assume further that in pursuing the maximum net revenue, each firm acts independently; i.e.;

$$dq_j/dq_i = 1, \text{ if } i = j \qquad (56)$$

$$= 0, \text{ if } i \neq j$$

Now, equation (55) becomes:

$$X + q_i(dF/dQ) - (dG_i/dq_i) = 0 \qquad (57)$$

Substitute into (57) the following quantites :

$$\alpha_i = q_i/Q, \text{ the market share of firm i} \qquad (58)$$

$$\epsilon = (X/Q)(1/\frac{dF}{dQ}), \text{ price elasticity}$$

then:

$$X\ (1 + \alpha_i/\epsilon) - dG_i/dq_i = 0 \qquad (59)$$

If α_i is so small and/or ϵ so large, such that $\alpha_i/\epsilon = 0$ then the necessary condition for a maximum is the exact condition for competition:

$$X = dG_i/dq_i = MC$$

If there is only one firm in the industry, $\alpha_i = 1$ implies that $q_1 = A$, then the necessary condition for a maximum becomes the condition for maximum net return of a monopoly:

$$X + Q(dF/dQ) - dG/dQ = 0, \text{ or}$$

$$MR = MC$$

If collusion could be represented by a functional relation among the firms' outputs; e.g. in implicit form:

$$\Psi (q_1, q_2, \ldots, q_n) = 0$$

then the assumption in (56) is:

$$dq_j/dq_i = 1, \text{ if } i = j$$

$$= (d\Psi/dq_i)(d\Psi/dq_j) \neq 0, \text{ if } i \neq j$$

also, $dQ/dq_i = d\Psi/dq_i$

and thus equation (55) becomes:

$$X + q_i(dF/dQ)(d\Psi/dq_i) - dG_i/dq_i = 0 \qquad (60)$$

(59) becomes:

$$X(1 + (\alpha_i/\varepsilon)(d\Psi/dq_i)) - dG_i/dq_i = 0 \qquad (61)$$

In any case, it is clear that the value of market share α_i is relevant in leaving the state of competition to go towards collusion. In the particular situation of the three oil companies, two companies have market shares above 10%

as shown in (49) so that the factor α_i/ε can not be ignored, and hence collusion is more likely than competition.

As a general rule, collusion occurs whenever it is more profitable to all of the members than their other feasible alternatives. For collusion to dominate competition, the joint profit must exceed the combined competitive returns and also none of the members may obtain a higher return by some other strategy given that all others stick to the collusive agreement.

B. EFFICIENT INDUSTRY ORGANIZATION [20]

Within the industry, the process of collusion forces the k firms, $k \leq n$, to be active (38) while the other (n-k) inactive. The following discussion is a generalized version of the previous one about determining the optimal number of firms in in the industry and the optimal allocation among the firms for a given total output. (The crude production is determined by PERTAMINA).

Let the total cost function of the industry be denoted by:

$$C(k) = \sum_{i=1}^{k} c_i \tag{62}$$

It is convenient to index the firms with a continuous parameter σ:

$$C(k) = \int_0^k c(\sigma)N(\sigma)d\sigma \tag{63}$$

where $N(\sigma)$ is the number of firms of type σ.

Similarly, the industry's total output:

$$Q(k) = \int_0^k q(\sigma)N(\sigma)d\sigma \tag{64}$$

The discussion in V.D.2. is a maximization problem for each firm, whose results can also be derived from the following non-linear programming problem: efficient industry organization problem:

$$\begin{aligned} &\text{min. } C(k) && (65)\\ &\text{s.t. } Q(k) \geq Q, \text{ a constant}\\ &\qquad k \geq 0\\ &\qquad q(k), \text{ positive function} \end{aligned}$$

The Lagrangian is given by:

$$C(k) + \lambda(Q - \int_0^k q(\sigma)N(\sigma)d\sigma) \tag{66}$$

where λ is the Lagrange multiplier.

The necessary conditions for a minimum:

$$dC/dk - \lambda q(k)N(k) = 0 \tag{67}$$

$$dC/dq - \lambda \int_0^k N(\sigma)d\sigma = 0 \tag{68}$$

Differentiation of (63) will give:

$$dC/dk = c(k)N(k)$$

$$dC/dq = \int_0^k (dc/dq)N(\sigma)d\sigma$$

and if those are substituted into (67) and (68):

$$(c(k) - \lambda q(k))N(k) = 0$$

$$\int_0^k ((dc/dq) - \lambda)N(\sigma)d\sigma = 0$$

which result in:

$$dc/dq = \lambda, \text{ for all } \sigma, 0 \leq \sigma \leq k \qquad (69)$$

$$dc/dq = c(k)/q(k)$$

In words, the first condition means that for all active firms there must be a common marginal cost. This can be checked for the particular case in (40), $\lambda = -2b, \forall \sigma \leq k$. The second condition is applicable for the marginal firm, that is the last firm that it just pays to operate. If initially the firms' index is ordered with respect to their minimum average cost, the condition means that the marginal firm operates at the largest minimum average cost. This condition has been used in (43).

C. CONCLUDING REMARKS

The model proposed involves a specific form of monopolistic competition. It discusses one set of participants, the producing firms. This set consists of two types of players, whose conflict behaviors are explained within the context of a game. The first type of players, the national oil companies: PERMINA, PERTAMIN and PERMIGAN compete among themselves in their joint ventures to produce crude oil with the second type of players, the foreign investors.

The paper successfully justifies the merging of the three companies into PERTAMINA, and that collusion is preferable to continual competition.

For future studies, the discussion could be deepened and broadened to get into the bargaining process itself, instead of accepting the results as givens. The possibility of the model to be used as a tool of prediction could also be explored, instead of being used as a tool of explanation only.

LIST OF REFERENCES

1. Aumann, R. J., "Disadvantageous Monopolies", Journal of Economic Theory, v. 6, p. 1-11, Novermber 1973.

2. Bradley, P. G., The Economics of Crude Petroleum, North-Holland Publishing Company, 1967.

3. Glassburner, B., Editor, The Economy of Indonesia, Cornell University Press, 1971.

4. Hadar, J., Mathematical Theory of Economic Behavior, Addison-Wesley Publishing Company, 1971.

5. Haynes, J., "Indonesia Offshore Drilling Increases", World Oil, p. 120-124, November 1969.

6. Hunter, A., "The Indonesian Oil Industry", Australian Economic Papers, v. 5, p. 59-106, June 1966.

7. Kohlberg, E., "On the Nucleolus of a Characteristic Functien Game", SIAM J. Appl. Math., v. 20, no. 1, p. 62-66, January 1971.

8. Lucas, W. F., "Some Recent Development in n-Person Game Theory", SIAM Review, v. 13, no. 4, p. 491-523, October 1971.

9. Lucas, W. F., "An Overview of the Mathematical Theory of Games", Management Science, v. 18, no. 5, part 2, p. 1-19, January 1972.

10. Penrose, E. T., The Large International Firm in Developing Countries, the Petroleum Industry, The M.I.T. Press, 1968.

11. Rapoport, A., Two Person Game Theory, the Essential Ideas, Ann Arbor, the University of Michigan Press, 1970.

12. Rapoport, A., n-Person Game Theory, Concepts and Applications, Ann Arbor, the University of Michigan Press, 1970.

13. Scherer, F. M., Industrial Market Structure and Economic Performance, Rand McNally & Company, 1971.

14. Schmeidler, D., "The Nucleolus of a Characteristic Function Game", SIAM J. Appl. Math., v. 17, no. 6, p. 1163-1169, November 1969.

15. Schurr, S. H. and Homan, P. T., Middle Eastern Oil and the Western World, Prospects and Problems, American Elsevier Publishing Company, Inc., 1971.

16. Shapley, L. S., "On Balanced Sets and Cores", RAND Corporation Memorandum, 1966.

17. Shapley, L. S. and Shubik, M., "Pure Competition, Coalitional Power and Fair Division", International Economic Review, v. 10, no. 3, p. 337-361, October 1969.

18. Shubik, M., Strategy and Market Structure, John Wiley & Sons, Inc., 1968.

19. Stigler, G. J., The Organization of Industry, Richard D. Irwin, Inc., 1968.

20. Telser, L. G., Competition, Collusion and Game Theory, Aldine Atherton, Inc., 1972.

21. Voneiff, P., "Indonesia Flowing Offshore Crude to Japan", Petroleum Engineer, p. 14-24, June 1972.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Naval Postgraduate School Department of Operations Research and Administrative Sciences Monterey, California 93940	1
4.	Associate Professor P. M. Carrick Department of Operations Research and Administrative Sciences Monterey, California 93940	1
5.	Assistant Professor K. Terasawa Department of Operations Research and Administrative Sciences Monterey, California 93940	1
6.	DIKLAT/SPERSAL, MABAL Jl. Gunungsahari 67 Jakarta, Indonesia	1
7.	Institute Ilmiah AL Cipulir Jakarta, Indonesia	1
8.	Mayor Laut (E) Suyoso Sukarno DIKLAT/SPERSAL, MABAL Jl. Gunungsahari 67 Jakarta, Indonesia	1
9.	PERTAMINA Jl. Perwira 2 - 6, P. O. Box no. 12 Jakarta, Indonesia	1

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

ORIGINATING ACTIVITY (Corporate author)

Naval Postgraduate School
Monterey, California 93940

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

REPORT TITLE

Monopolistic Competition in Indonesian Petroleum Industry

DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Master's Thesis; September 1973

AUTHOR(S) (First name, middle initial, last name)

Sujoso Sukarno

REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September, 1973	79	21

a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Postgraduate School Monterey, California 93940

13 ABSTRACT

Competition has been considered to be the prime force which leads to an optimal solution of the economic problem. But the underlying assumptions used in the current equilibrium theory are so empirical, such that in the practical world there just is no competition as proposed by the theory.

In fact, in real life economic competition does not exist in its pure form, but in a more realistic form instead: the monopolistic competition. A game theoretical approach is implemented to find answers to the issues of this particular phenomenon.

Petroleum environment in Indonesia provides the structure for the economic analyses.

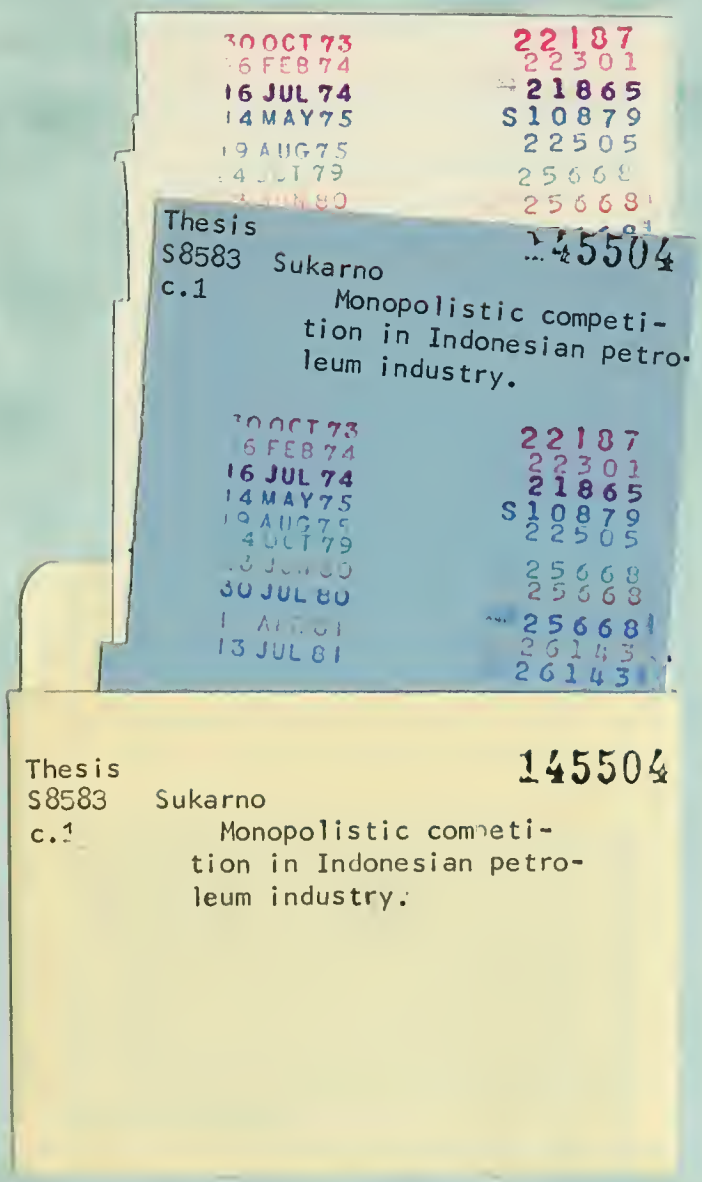
DD FORM 1 NOV 68 1473 (PAGE 1)

S/N 0101-807-6811

Security Classification

A-31408

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
onopoly						
ndonesian Industry						
ompetition						
ndonesian Petroleum						


30 OCT 73 22187
6 FEB 74 22301
16 JUL 74 21865
14 MAY 75 S10879
19 AUG 75 22505
4 OCT 79 25668
30 JUL 80 25668
1 AUG 81 25668
13 JUL 81 26143
Thesis
S8583 Sukarno
c.1 Monopolistic competition in Indonesian petroleum industry.
145504

Thesis
S8583 Sukarno
c.1 Monopolistic competition in Indonesian petroleum industry.
145504

thesS8583
Monopolistic competition in Indonesian p
3 2768 001 00911 1
DUDLEY KNOX LIBRARY